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Bringing Exoplanet Habitability Investigations to High School

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A. Introduction Habitability, a.k.a. habitat suitability, is a topic typically discussed in Biology class. We present here a curriculum unit that introduces the topic of global-scale planetary habitability in a Physics classroom, allowing students to emulate the process of doing cutting-edge science and re-framing an otherwise "typical" physics unit in a more engaging and interactive way.

At its core, habitability is a temperature-dependent quality that is introduced and explored during the Energy unit. Students conducted a research project with the goal of determining the habitability state for a chosen exoplanet.

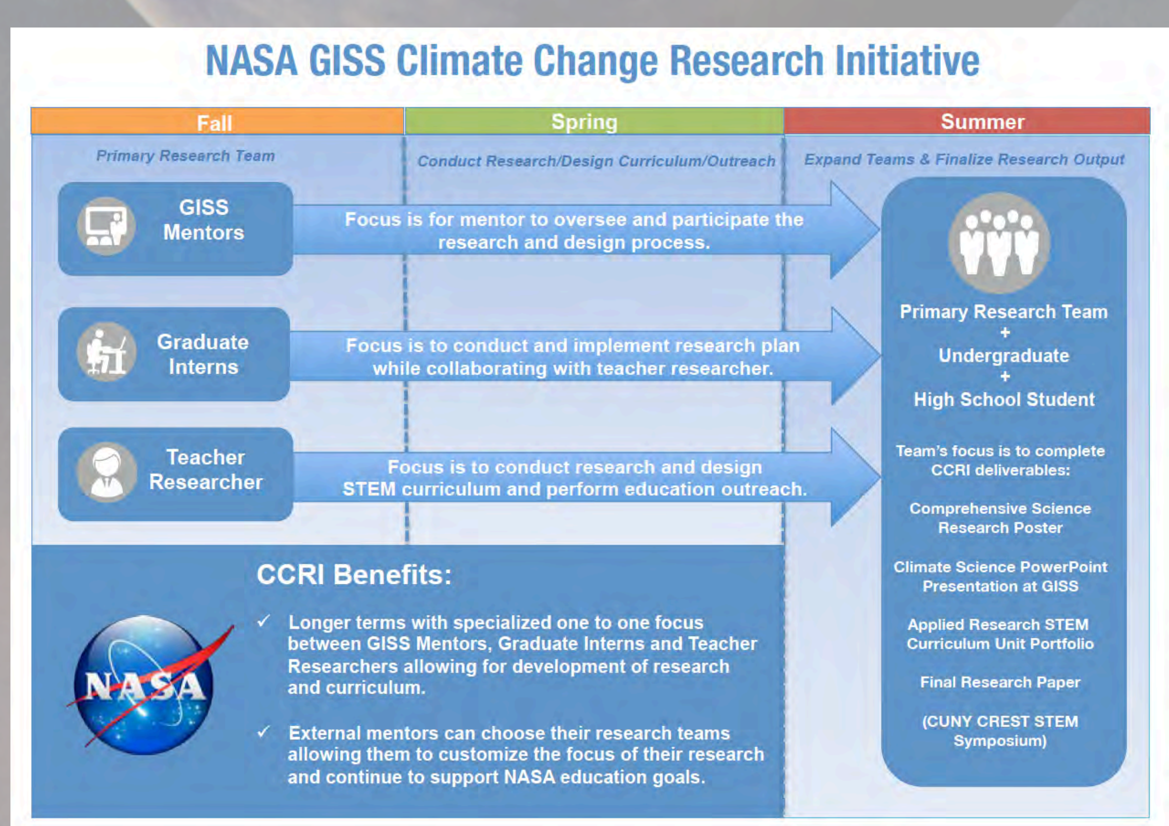
Classroom implementation was modeled after the CCRI scientist-mentor's actual research plan. Students first discussed 4 basic habitability factors and explored these variables through climate modeling software. Students then chose an exoplanet to evaluate using these habitability factors, an activity that required them to perform authentic research on the exoplanet and its host star.

Students also developed hypotheses about factors beyond currently available mission data, such as atmospheric composition and surface albedo of their exoplanet. They then used the modeling software to collect data, test hypo-theses, and draw conclusions. Lastly, students communicated their findings in a poster session and presentation at the high school's annual science symposium.

By bringing actual science and research practices to the classroom, the students were not only more actively engaged with the required Physics course content, but also gained a better understanding of how scientific research is done.

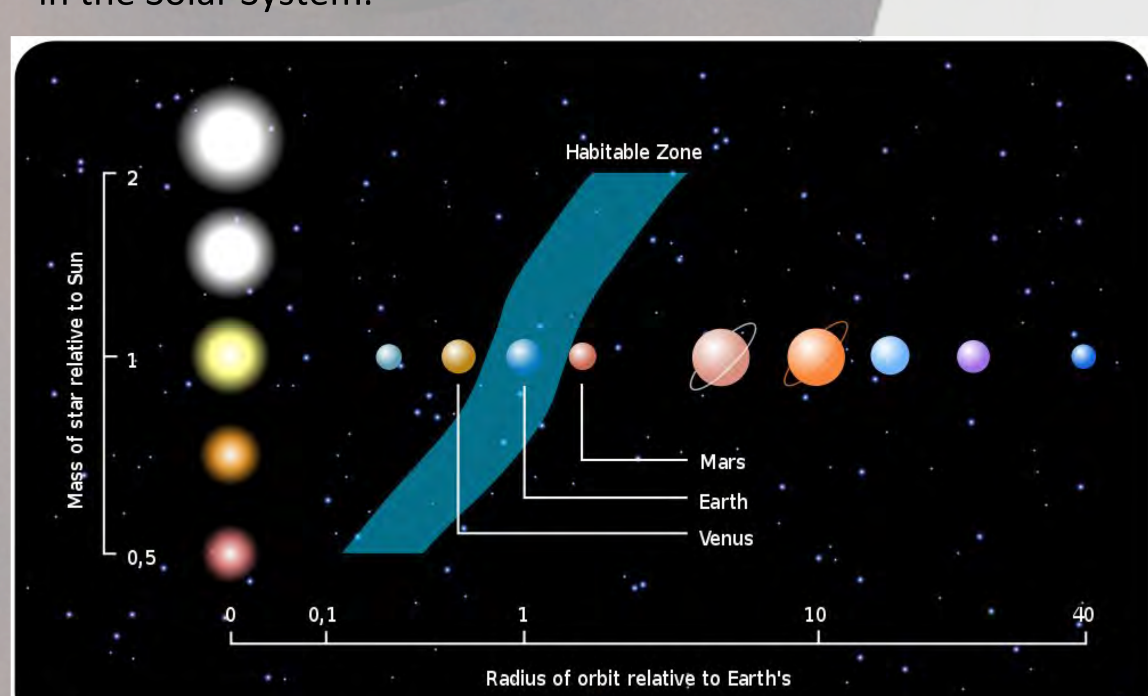
B. CCRI Program

Program Overview: The NASA GISS Climate Change Research Initiative (CCRI)[1] provides an opportunity for STEM educators to work directly with NASA scientists, lead research teams, and develop STEM curricula for their current classes.



Research and Methods: The research project that inspired the unit plan described here involved the exploration of various factors that can influence an Earth-like planet's habitability state. A planet is considered potentially habitable for life as we know it if the planet receives enough energy from its host star to maintain liquid water on its surface (0˚C < t_{surf} < 100˚C).

The habitable zone (HZ) marks that orbital region around a star where the planet is neither too warm nor too cold for life as we know it. The CCRI team used EdGCM[2], an educational version of the NASA/GISS global climate model, to conduct experiments exploring orbital constraints on habitability. This project is an offshoot of funded research exploring the history of habitability in the Solar System.



C. Unit Overview

Brief Unit Summary: *Students are engaged in a project-based Energy unit that directly mimics CCRI research project and progression.*

Day	Topic	Activity
1	**Habitability:** definition, factors and exoplanets	1. Students complete habitability concept web 2. Students explore Exoplanet catalog[3] 3. Students record relevant habitability data for chosen exoplanet
2	**Climate simulation:** introduction of Mini-GEEBIT B3 model[4]	1. Students explore each habitability factor individually using the Mini-GEEBIT B3 model 2. Students create graphs of trends in temperature in response to varying each respective factor
3	**Exoplanet habitability:** model exoplanet using Mini-GEEBIT B3 model	1. Students discuss and determine model inputs for their specific exoplanet 2. Students analyze model output to determine habitability for their exoplanet
4	**Exoplanet habitability (continued):** manipulate exoplanet data for new model inputs	1. Students discuss and determine one habitability factor to change to increase habitability 2. Students input new data into the Mini-GEEBIT B3 model 3. Students analyze model output
5	**Habitability:** comparison of exoplanet data and manipul-ation with Earth-Sun system	1. Students share model outcomes with the class 2. Students compare exoplanet outputs with the Earth-Sun system

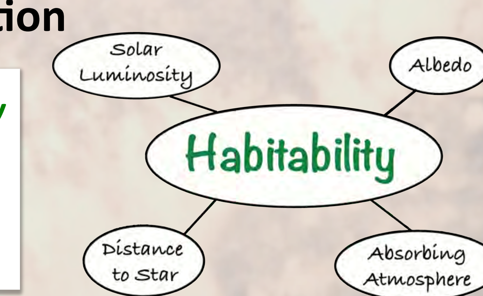
Student activities map clearly to multiple education standards

Next Generation Science Standards [5]	New York State Science Standards [6]	Common Core Standards [7]
HS-PS3-1 Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. **HS-PS3-2** Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).	4. Energy exists in many forms, and when these forms change energy is conserved. 4.1 Observe and describe transmission of various forms of energy. a) All energy transfers are governed by the law of conservation of energy.* b) Energy may be converted among mechanical, electro-magnetic, nuclear, and thermal forms.	**CCSS.ELA-LITERACY.RST.11-12.3** Follow precisely a complex multistep procedure when carrying out experi-ments, taking measurements, or perform-ing technical tasks; analyze the specific results based on explanations in the text. **CCSS.ELA-LITERACY.RST.11-12.4** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics. **CCSS.ELA-LITERACY.RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verify-ing the data when possible and corroborating or challenging conclu-sions with other sources of information. **CCSS.ELA-LITERACY.RST.11-12.9** Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understand-ing of a process, phenomenon, or concept, resolving conflicting information when possible.

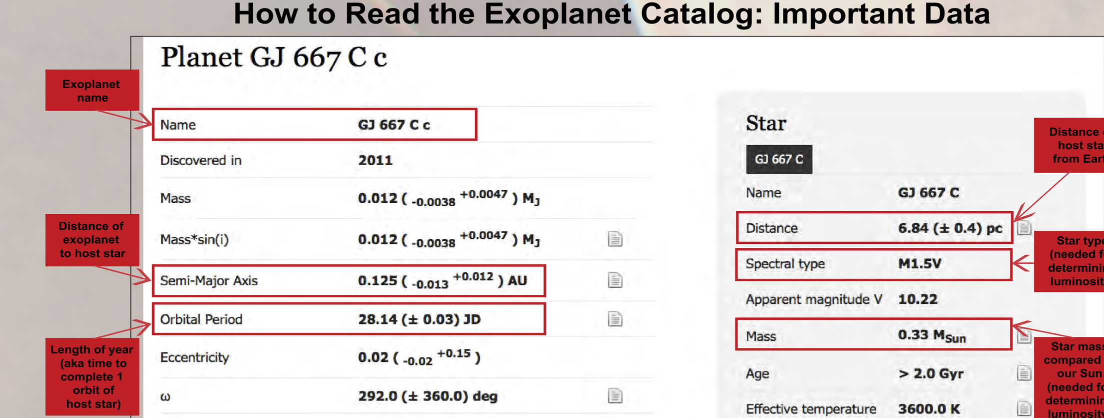
D. Classroom Implementation

Day 1: Habitability & Exoplanet Selection

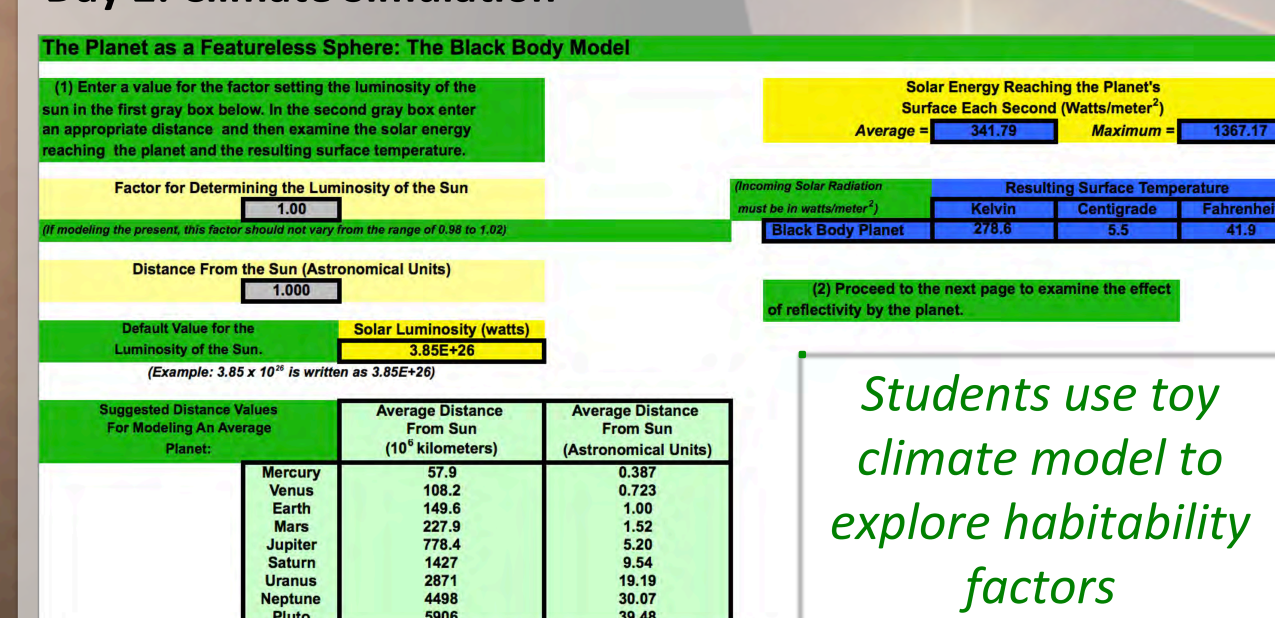
Students learn about habitability & the characteristics of the exoplanet they have selected



How to Read the Exoplanet Catalog: Important Data



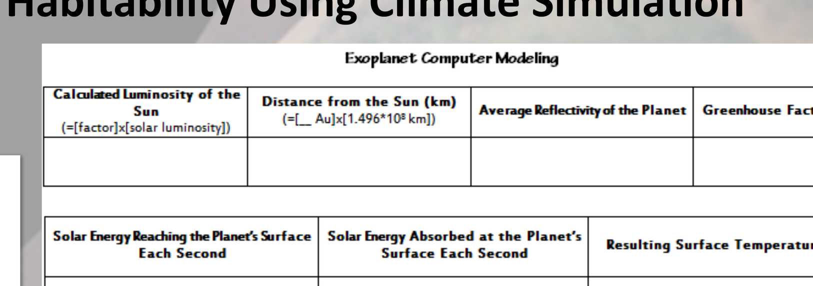
Day 2: Climate Simulation

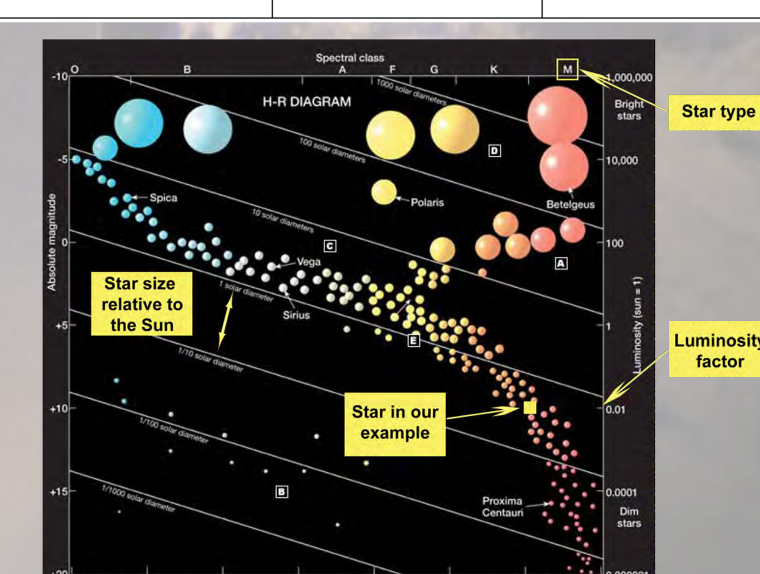


Students use toy climate model to explore habitability factors

Day 3/4: Exoplanet Habitability Using Climate Simulation

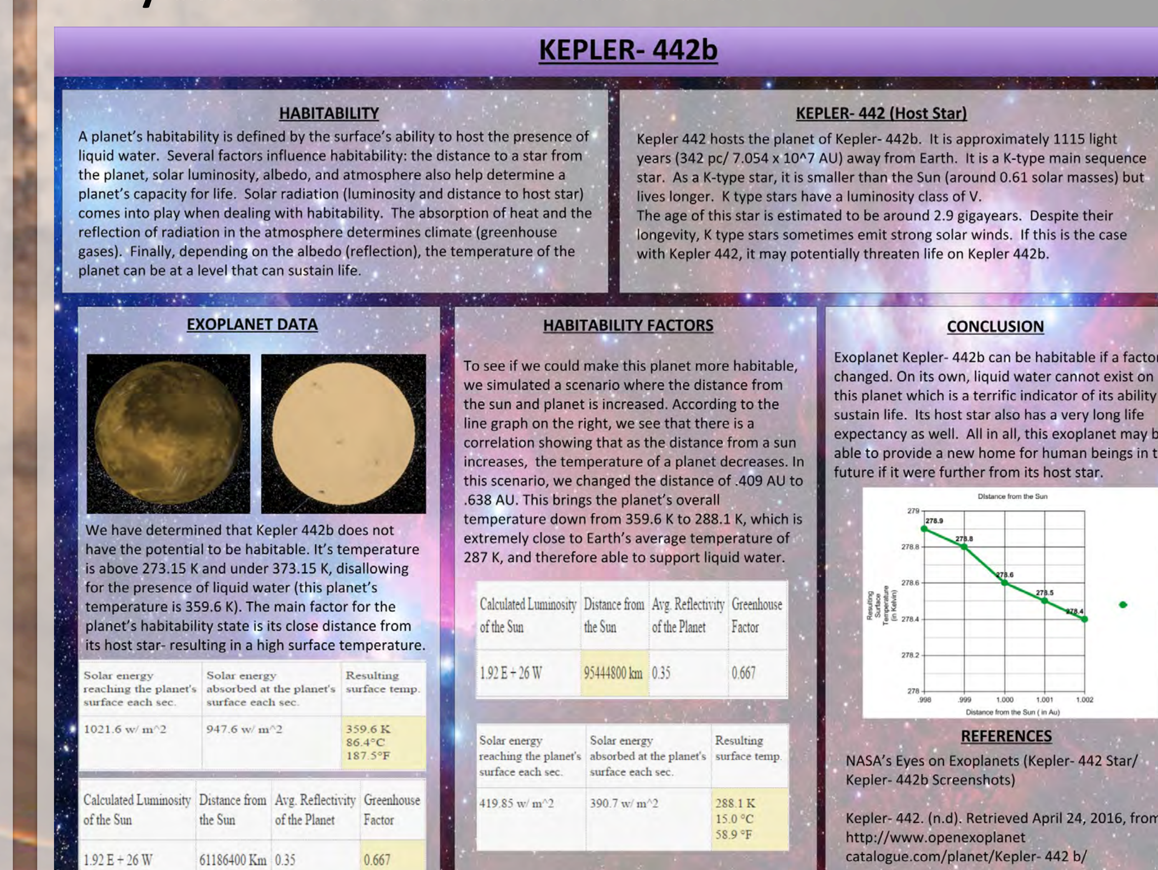
Students use toy climate model and astrophysical characteristics to determine habitability of their chosen exoplanet





D. Implementation (cont.)

Day 5: Student Poster Presentation



E. Summary

The CCRI collaboration between NASA scientist, Dr. Linda Sohl, and STEM educator, Mary Anne Woody, served as an impact-ful partnership. The scientist provided inspiration, content and resources for lessons, bringing actual scientific content and research practices to the high school classroom. As a result, the students were able to engage with an exciting and relevant topic, while expanding on the typical science content of a unit on conservation of energy.

Lastly, the project provided a genuine snapshot of a career in scientific research, one where the "right" answer is not always readily available, and informed interpretations are made. The students reported positive feedback for the project and recommended it for rising Physics classes. They were not only engaged in the subject material, but also enjoyed using the online simulations to be "experts" on their chosen exoplanet.

References

1. NASA Climate Change Research Initiative, http://www.giss.nasa.gov/edu/ccri/
2. EdGCM, The Educational Global Climate Model, http://edgcm.columbia.edu
3. Exoplanet Database, http://exoplanet.eu/catalog/
4. Mini-GEEBIT B3, http://icp.giss.nasa.gov/education/geebitt/
5. Next Generation Science Standards, http://www.nextgenscience.org/
6. New York State Science Standards, http://www.p12.nysed.gov/ciai/mst/sci/home.html
7. Common Core Standards, http://www.corestandards.org/ELA-Literacy/RST/11-12/

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